Hierarchical Triple Blackholes in Galactic Nuclei

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collaborate with

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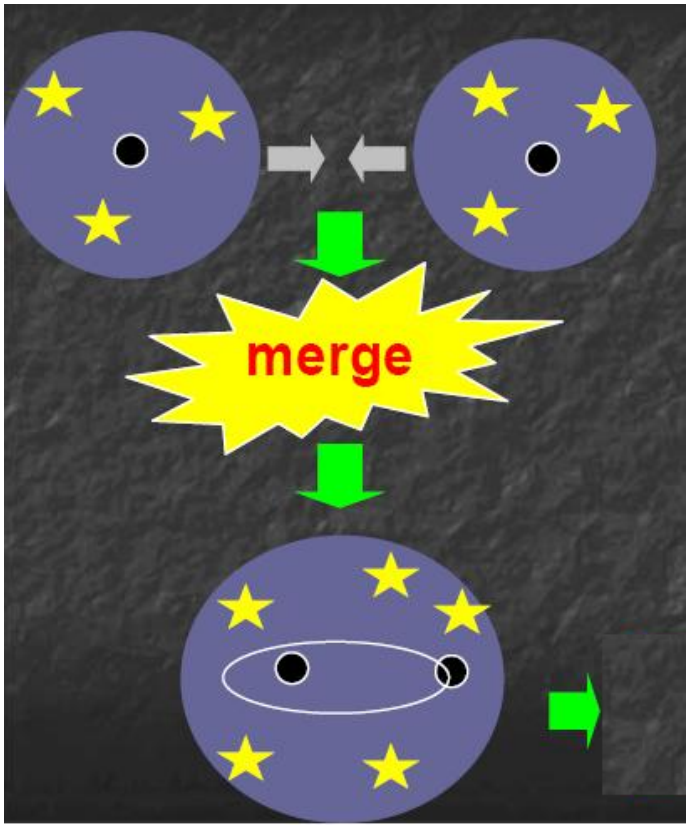
A part of this work is in

Iwasawa, Funato & Makino astro-ph/0511391, ApJ accepted

ABSTRACT

- **N-body study on dynamical evolution of triple massive blackhole (BH) systems in galactic nuclei**
- **Generally a hierarchical binaries of BHs is formed**
- **Two of BHs (inner binary) merge within the Hubble time via gravitational wave radiation**
- **The reason is Kozai mechanism which makes the inner binary highly eccentric.**
- **How to find them ?**

1. Introduction



A BH in a galaxy

⬇

Two galaxies merge

⬇

Two BHs are in the center

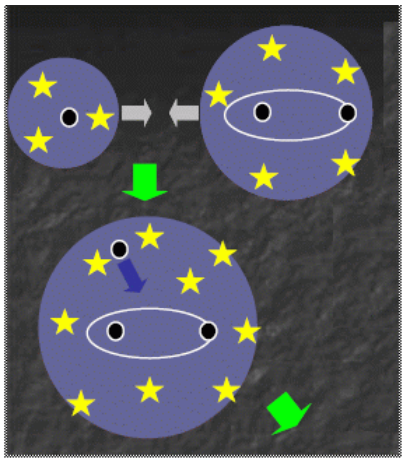
Life time of the binary BH >> Hubble Time

- *Begelman, Blandford, & Rees 1980*
- *Makino & Funato 2004*
- *Berczik, P., Merritt, D., & Spurzem, R. 2005*

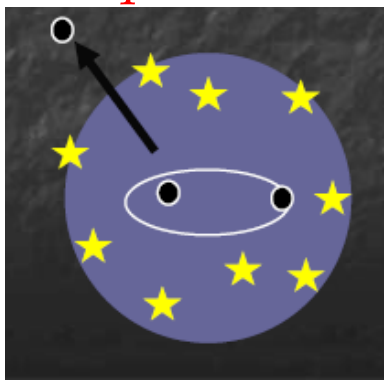
  ref: talk by Makino on Tuesday in this meeting

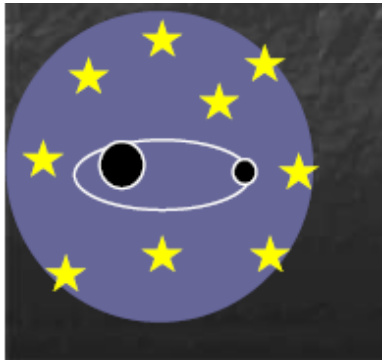
Next question :

What happen if a galaxy with a BH binary merges ?



escape without merger ?

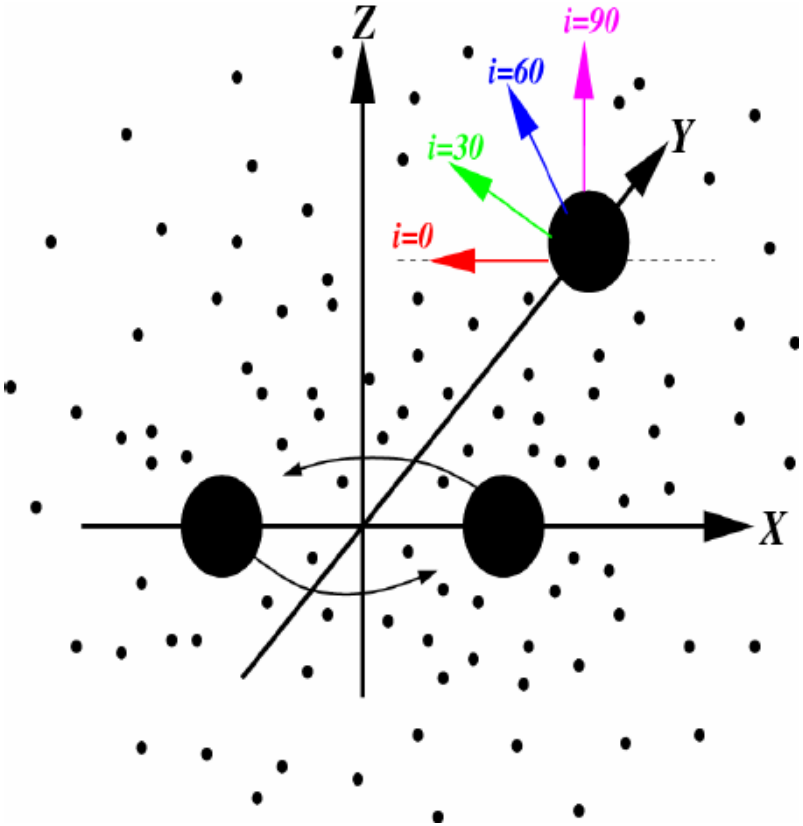




merge ?

What will happen ?

2. N-body simulation : Model



Galaxy : King ($W_0 = 7$)

$\sigma = 300$ **km/sec**

$N = 64$ **k**

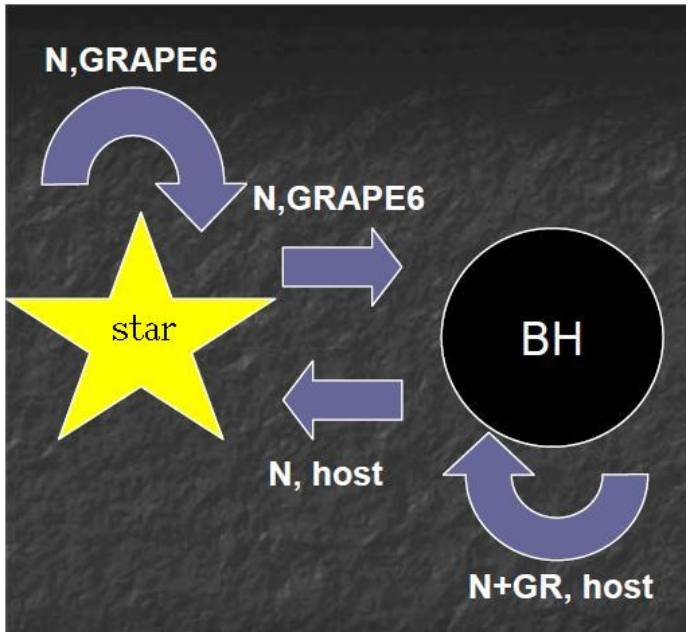
$M_{\rm gal} = 10^{10} M_\odot$

$M_{\rm BH} = 10^8 M_\odot$

$M_{\rm BH} = M_{\rm gal}/100$

Initial Distance of BBH and the 3rd $= 240pc$

Method



direct summation

4th order Hermite Scheme

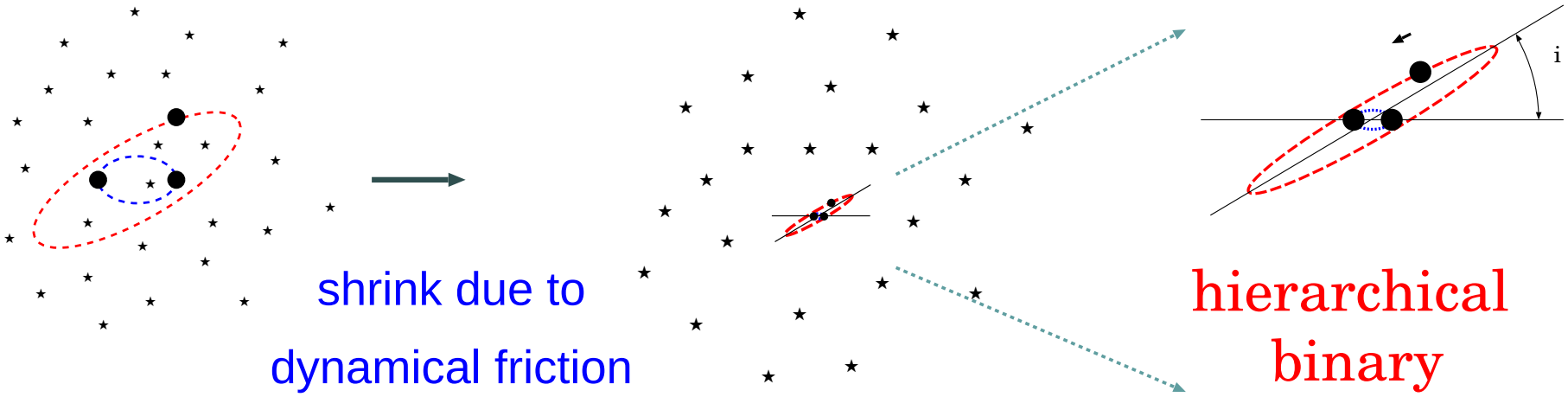
Post Newtonian

.

$$\mathbf{a} = -\frac{Gm_2}{r^3}\mathbf{r} + \frac{4G^2 m_1 m_2}{5r^3 c^5}\left[\left(-v^2 + \frac{2Gm_1}{r} - \frac{8Gm_2}{r}\right)\mathbf{v} + \frac{\mathbf{r}\cdot\mathbf{v}}{r^2}\left(3v^2 - \frac{6Gm_1}{r} + \frac{52Gm_2}{3r}\right)\mathbf{r}\right]$$

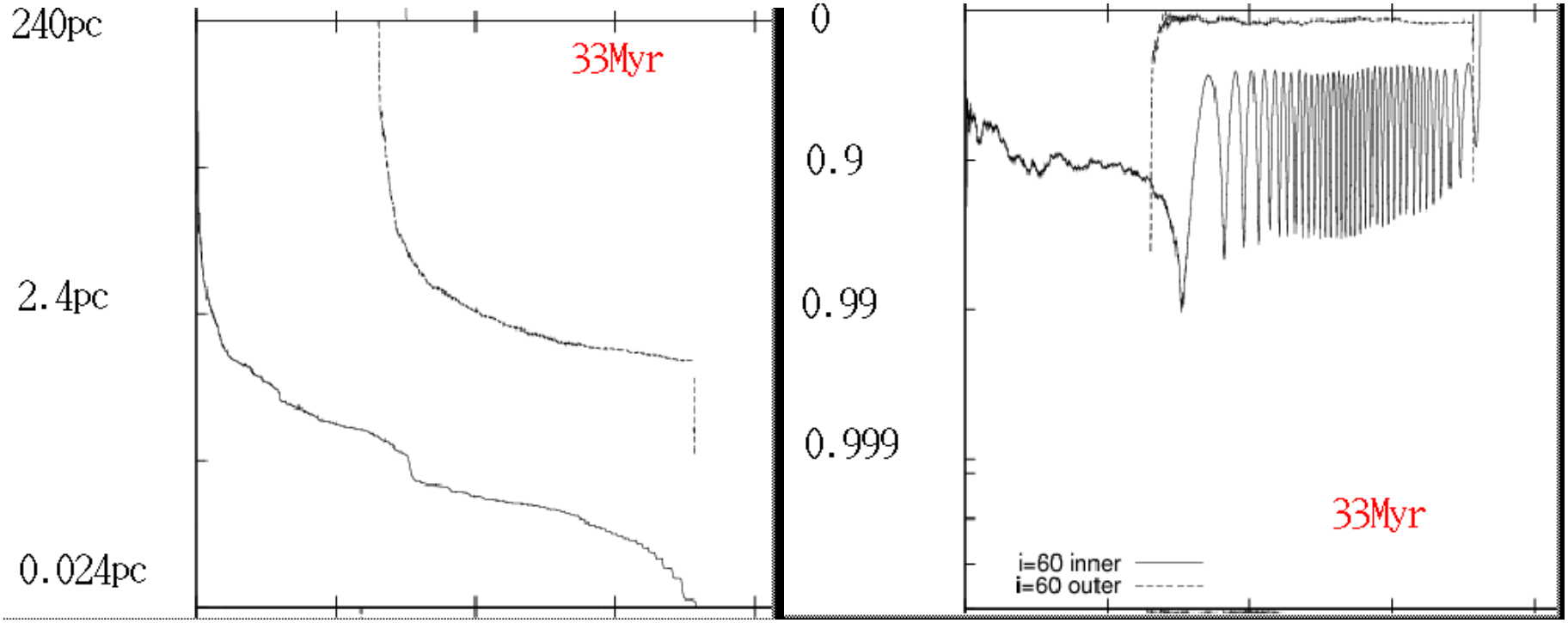
$\mathbf{r} = \mathbf{r}_1 - \mathbf{r}_2$ 、 $\mathbf{v} = \mathbf{v}_1 - \mathbf{v}_2$

3.1 Result I — Forming Hierarchical Triples



Left : Semi-Major Axis of the Inner and Outer binaries

Right : Eccentricity of the Inner and Outer binaries



. **time** **time**

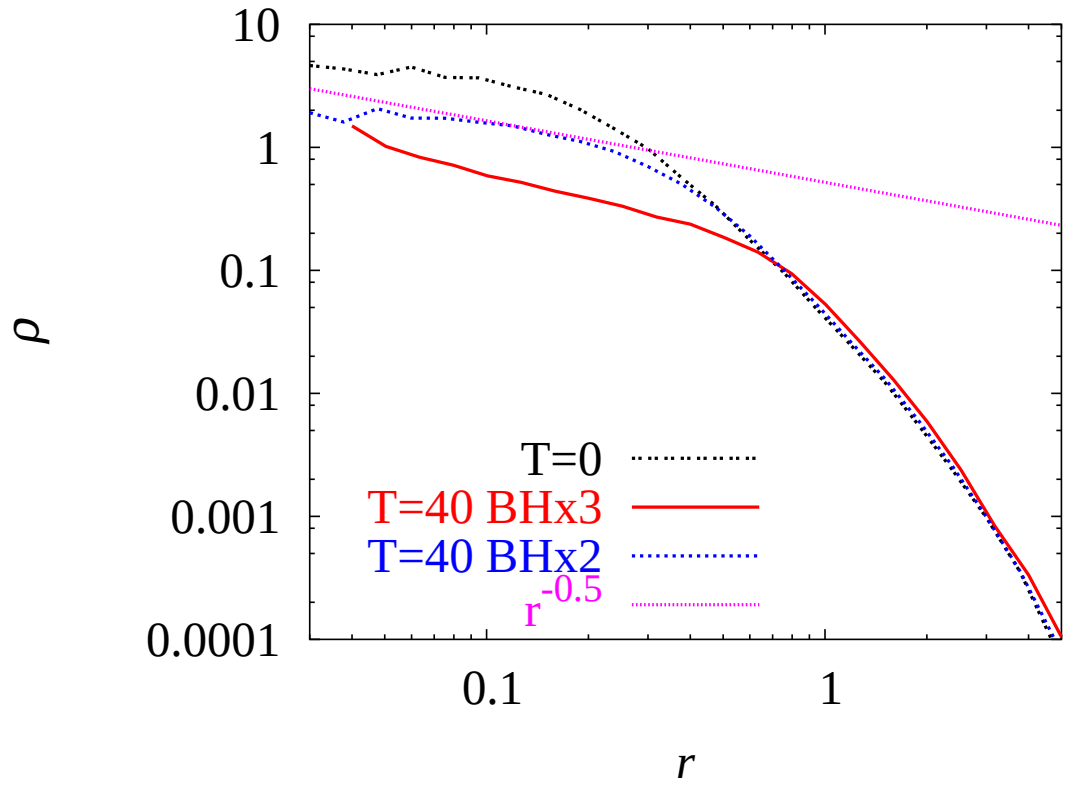
We carried out 6 runs changing the initial velocity of the 3rd BH,

Hierarchical Binaries in all cases

BHs merge in 3 out of 6 cases within 100 Myrs

. *Roughly 50 % !*

4. How to find the triple BH system ?



Density profile

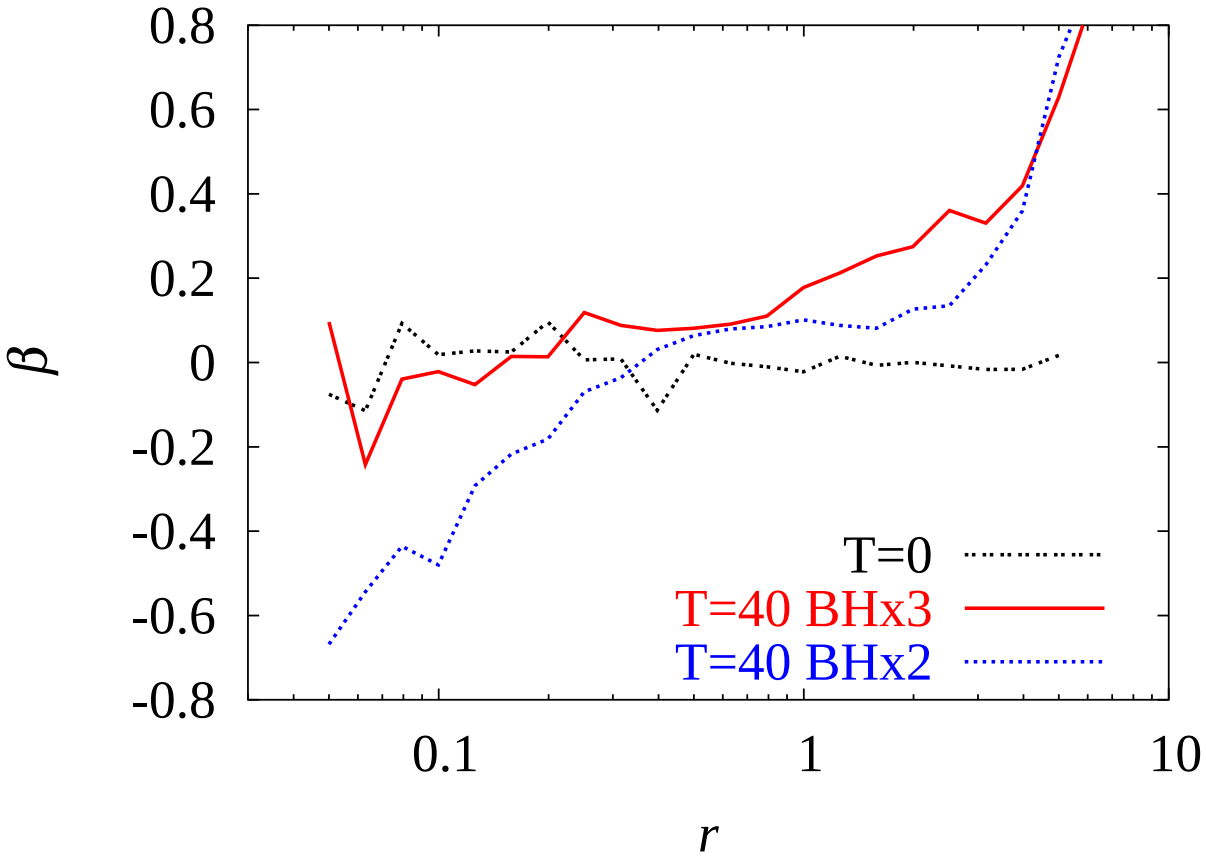
Extended shallow cusp

$$\propto r^{-0.5}$$

.

consistent with Nakano & Makino 1999a & 1999b

Velocity anisotropy : $\beta \equiv 1 - \frac{<v_t^2>}{2<v_r^2>}$



3BH:isotropic **2BH: tangential**

Find a galaxy with a

Shallow cusp $r^{-0.5}$

↓

in the cusp

orbit is tangential

↓

binary BHs

orbits are isotropic

↓

triple BHs

CONCLUSION

- **Generally a hierarchical Triple System of BHs is formed when galaxies with BHs merges**
- **Two of BHs of the inner binary are merged within 100M years due to the high eccentricity driven by Kozai mechanism**
- **$1 \sim 2$ BHs and 3 BHs can be distinguished from the structure of velocity distributions of stars in nuclei.**